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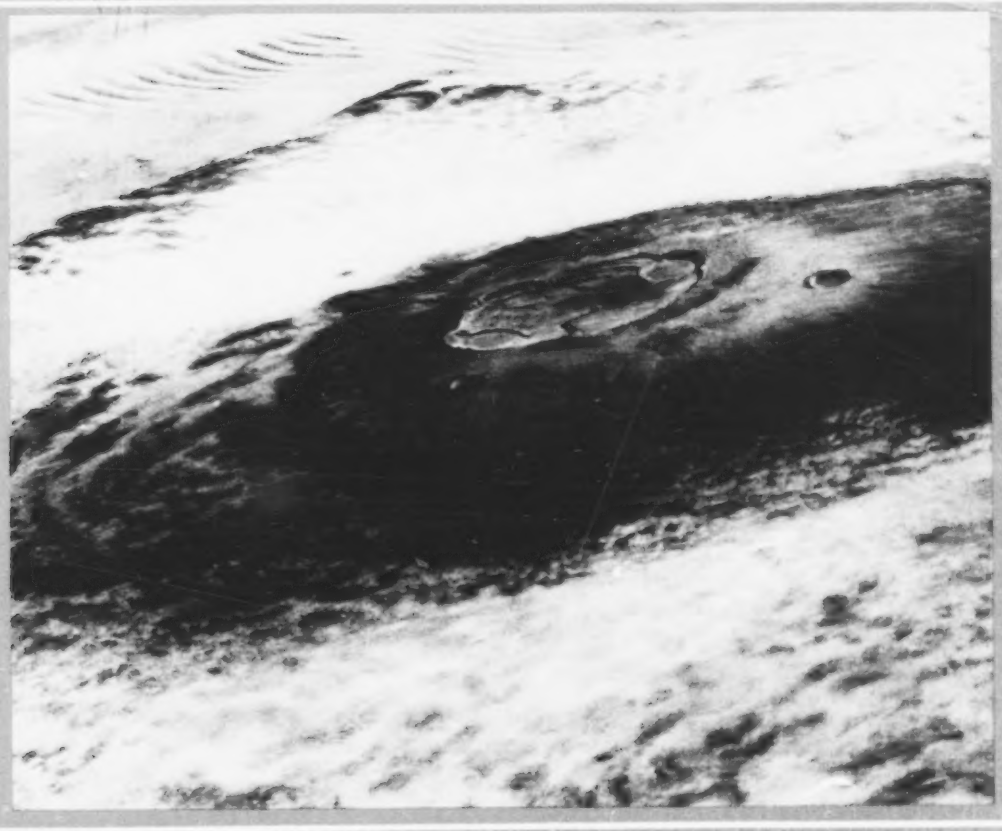
NASA SP-444

IMAGES OF MARS



The Viking Extended Mission

National Aeronautics and Space Administration

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IMAGES OF MARS

The Viking Extended Mission

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Foreword

Images from one of the most extraordinary of NASA's space missions are presented in this book. The Viking mission to Mars was conceived in 1968, and two spacecraft were launched to the planet seven years later. Viking 1 was scheduled to land on the Martian surface on July 4, 1976, the Nation's bicentennial, but, because of the unexpected rugged appearance of the originally chosen site, landing was delayed until July 20, 1976, the seventh anniversary of the first manned landing on the Moon. Since that time the two Viking landers and two orbiters have returned an enormous amount of information about the planet. The spacecraft were designed to operate for only 90 days, and initial expectations were that the spacecraft might last only a few weeks. No one could have predicted that at this time one of the two orbiters would still be operating, sending back pictures to Earth, and that both of the landers would still be operational. It is even now hard to comprehend that one of those landers might continue to operate for ten years or more.

The photographs and the texts in this volume provide an elegant look at the planet Mars as revealed by Viking during its extended mission. Some of the pictures were taken as recently as late 1979 and are therefore of particular interest.

Thomas A. Mutch
Associate Administrator
Office of Space Science

March 1980

Overview of Mars

Mars, named after the Roman war god because of its angry, red appearance in the night sky, has been known to man since prehistoric times. It is the fourth planet from the Sun, after Mercury, Venus, and Earth. Like these planets it has a mostly solid surface. in contrast with the outer planets which are composed mostly of gas. Mars is just slightly more than one-half as large as Earth, having a radius of 3393 km (2108 miles). The Martian day is just over 24 hours long, but the year on Mars is 687 days or 1.9 Earth years. The two moons of Mars were discovered in 1877 by Asaph Hall, and named by him Deimos (Terror) and Phobos (Fear) after the two attendants of Mars. Phobos, the inner and larger satellite has a diameter of 24 km (15 miles) and circles Mars every 7.6 hours at an altitude of 6000 km (3700 miles). Deimos is 12 km (7.5 miles) across and circles the planet every 1.3 days at an altitude of 24 000 km (15 000 miles).

The canals discovered by Schiaparelli in 1877 and described by many observers since that time have not been identified as such in images returned from various spacecraft. Instead, the planet has been revealed to be extraordinarily diverse in both geology and meteorology.

Huge volcanoes suggest sustained activity that appears to have continued up to the present day. Gigantic floods have flowed across the surface periodically, deeply scouring the terrain and cutting large channels. There are also smaller channels indicative of slow erosion by running water in the manner that terrestrial river valleys form. The channels are puzzling because liquid water cannot exist on the Martian surface under present conditions; it would either freeze or rapidly evaporate. The channels, therefore, suggest different climatic conditions for the past. Huge canyons indicate faulting and land sliding on a grand scale, while layered deposits at the poles suggest sustained cyclic sedimentation. Although no liquid water is at the surface, considerable evidence exists for ground ice, below which liquid water could be present. Most impact craters are surrounded by flow patterns that indicate that the material ejected had a mud-like consistency, as if the impact had penetrated the permafrost layer to excavate the water-rich material from below.

Since the rotation axis is inclined 25°, the planet has seasons just like Earth. However, the eccentricity of the orbit around the Sun causes the seasons in each hemisphere to be of unequal lengths and intensities. The south has short, hot summers and long, cold winters, whereas the seasons in the north are less extreme.

The Martian atmosphere is thin, approximately one one-hundredth that of Earth, and consists primarily of carbon dioxide. Polar caps, also composed of carbon dioxide, advance and retreat with the seasons. It is thought that the carbon dioxide migrates from pole to pole between the winter season for each hemisphere. So much of the atmosphere condenses in the polar cap formation that the atmospheric pressure may drop one-third in the process.

Temperatures have a wide daily and seasonal variation. Polar temperatures during the winter may reach lows of −140° C (−225° F), whereas noonday temperatures at the equator may reach 20° C (68° F). Surface temperatures at the Viking Lander 1 site have been noted to vary approximately 75° between predawn and midafternoon measurements during summer in the north. Temperatures ranged from a low of −88° C (−158° F) to a high of −12° C (−21° F).

For most of the year the atmosphere is relatively calm, with wind speeds rarely exceeding 5 m/sec (11 mph); however, during the southern summer violent storms develop which can result in winds in excess of 50 m/sec (110 mph).

As Viking approaches its anniversaries of arrivals and landings on Mars, one of each in July and September of 1976, this booklet presents some of the phenomena that have been observed during the 2 Mars years (4 Earth years) of operation.

Mars has enormous volcanos, most of which are in the region of Tharsis. Olympus Mons, pictured here, is 27 km high (17 miles) and surrounded by a circular cliff 500 km (300 miles) across. Close-up pictures of the cliff show lava flows draped over the cliff and extending far beyond it so that the volcano is actually about 700 km (430 miles) across. By comparison the largest volcanoes on Earth, those in Hawaii, are 120 km (75 miles) across at their bases on the ocean floor. The large Martian volcanoes strongly resemble those in Hawaii in that they have large summit craters, long thin flows, lava channels, and lava tubes. The resemblance is so strong as to suggest similar basaltic composition for the lava. Many parts of Olympus Mons are devoid of impact craters, indicating a very young age. Indeed the volcano may still be active, although the time interval between eruptions is probably long. The large size suggests that it has been active for at least a billion years.

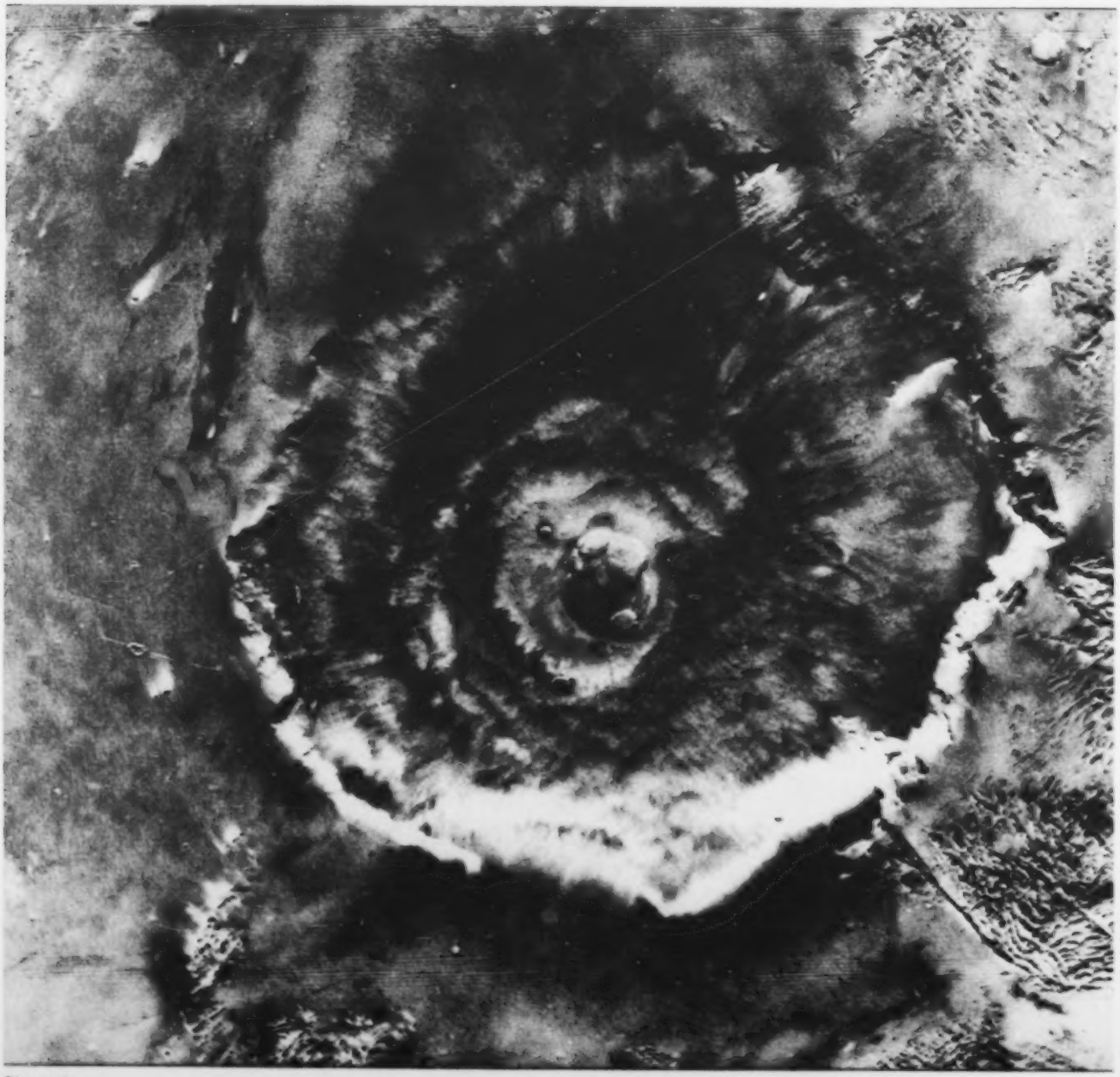
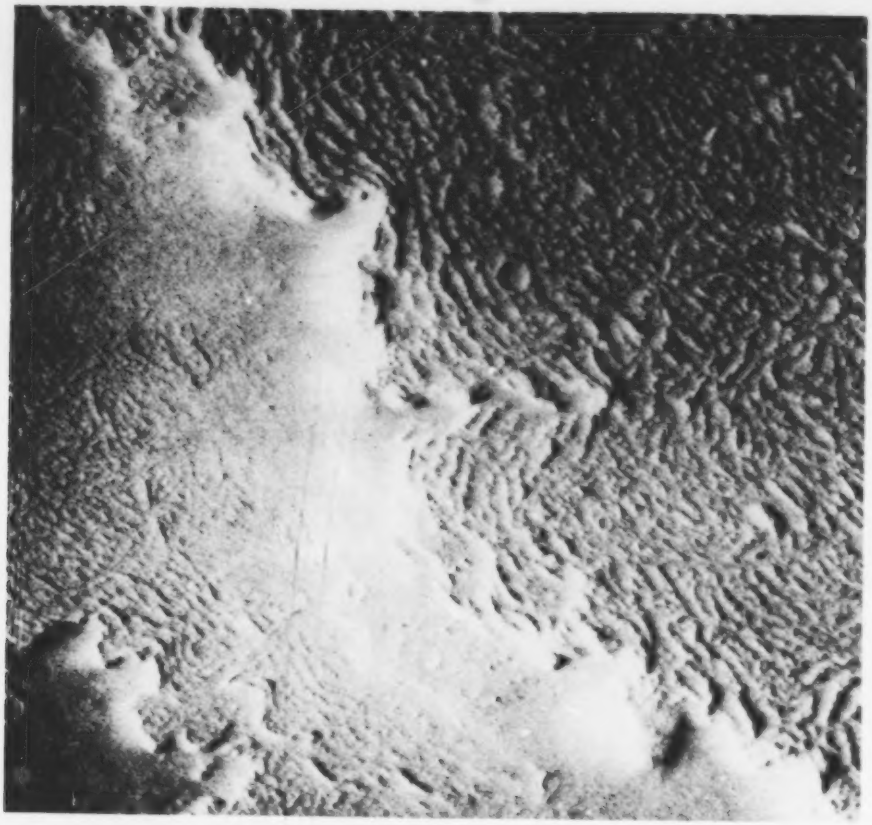


Figure 1



Around the volcanoes and in several other areas of the planet are vast lava plains similar to those of the lunar maria. Individual lava flows may be hundreds of kilometers long and cover thousands of square kilometers of the surface. Shown here is a high-resolution view of superimposed lava flows. On the surface of the flows are parallel ridges that probably formed as the cooler upper parts of the flow moved along and crumpled. The edge is marked by a cliff approximately 30 m (100 ft) high. Bright dust has accumulated at the base of the cliff, probably as a consequence of wind during planetary dust storms. The area shown is 12.5 km (8 miles) across.

Figure 2

On some volcanic plains are many small volcanic cones. This view of Isidis shows numerous low mounds with summit pits, many arranged in long lines. Most of the mounds are about 500 m (⅓ mile) across. They resemble terrestrial spatter cones and spatter ramparts that accumulate from globs of lava that have been thrown out from a volcanic vent. The alinement of the vents probably reflects faults in the surface below the volcanic materials. Why some plains are covered with spatter cones and others have large lava flows is not known, but it may be connected with the rate at which the lava is erupted, with large eruption rates causing flows and smaller eruption rates causing cones. Another possibility is that the lava that formed the cones seen here was more viscous than the lava that formed the flows shown in the preceding picture.

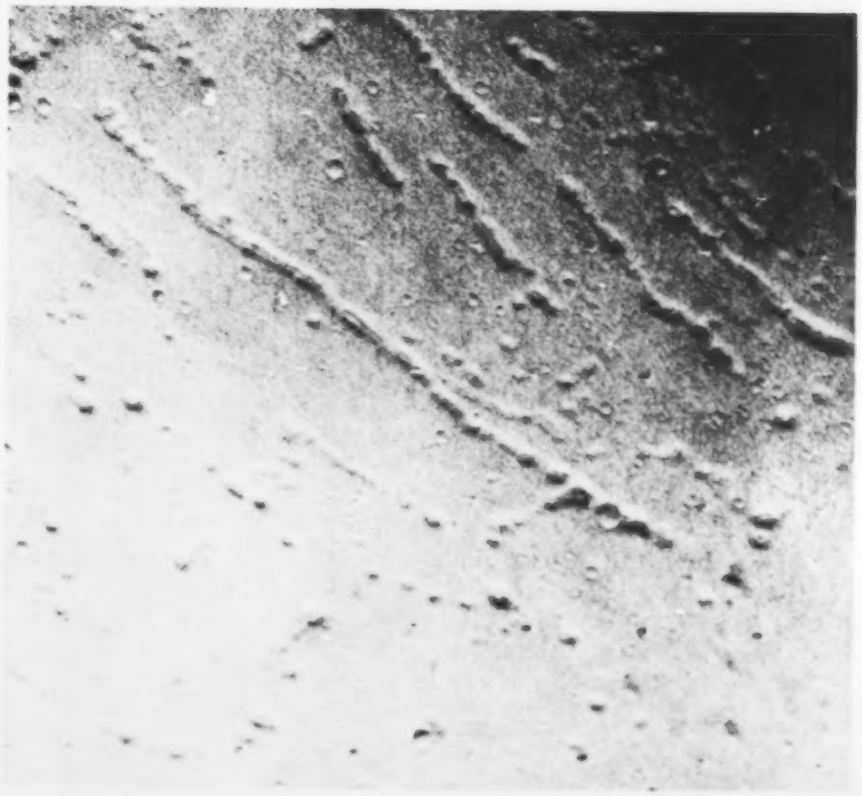


Figure 3

Figure 4

An old faulted surface (to the right) is embayed by younger smooth lava plains (to the left). Near the center of the picture is a small volcano 4 km across with an elongate summit vent. In this area, called the Tempe Plateau, such small volcanoes are relatively common and contrast sharply with the huge shield volcanoes in Tharsis to the southwest. Most of the small volcanoes are situated on faults similar to those which form the cliffs to the right. The faults are believed to be the result of deformation caused by the weight of the large bulge in the Martian crust centered over Tharsis. The area shown is 58 km (36 miles) across.

Figure 5

A puzzling feature of the Martian surface is its large channels. Many start full size, with no tributaries, and have many characteristics in common with large terrestrial flood features. Some are of such enormous size that discharges of more than 10 000 times the normal discharge of the Amazon are implied. Here you see one of the largest flood features, Kasei Vallis, in places more than 300 km (180 miles) across. The ground is deeply scoured where tear-drop-shaped islands have formed around obstacles such as craters and low hills. The flood apparently swept northward and then turned eastward as it converged on some deeply incised channels. The high-resolution view shows a part of the channel floor. The scoured surface has been deeply dissected either during the waning stages of the flood or subsequently by some other process such as wind erosion. The detailed image is 30 km (18.5 miles) across. The height of the cliffs is not known but probably exceeds 1 km (3200 ft).

Figure 6

Figure 7

Some large channels start near volcanoes. The ones seen here start near the large volcano Elysium Mons and wind their way to the northeast for several hundred kilometers. In this case flow has been restricted to discrete channels, unlike the flow that scoured broad areas and formed Kasei Vallis. Apparently the fluid repeatedly overflowed the banks to form a complex array of interconnected channels. The origin of these channels is controversial. Because the channels start so near a volcano, they could be lava channels, although such extensive lava channels are unknown on Earth. Alternatively, the channels might have been cut by water released from the melting of ground ice during volcanic eruptions. The area shown is 180 km (110 miles) across.

Slow erosion may have formed this channel by a process similar to the development of terrestrial river valleys. This kind of channel is characterized by well-developed tributary systems and is very common in the older terrains. Nirgal Vallis, seen here, is one of the largest of this type, more than 500 km (310 miles) long. The tributary network is very open; the individual branches are deeply incised, with steep walls, and the areas between the branches are undissected. These characteristics suggest that the channel formed by ground water sapping rather than by surface runoff. The water could have been derived from ground ice or from water beneath a permafrost layer. In either case, more temperate climatic conditions than those which presently prevail are implied. For scale, the high-resolution image shows an area 80 km (50 miles) across.

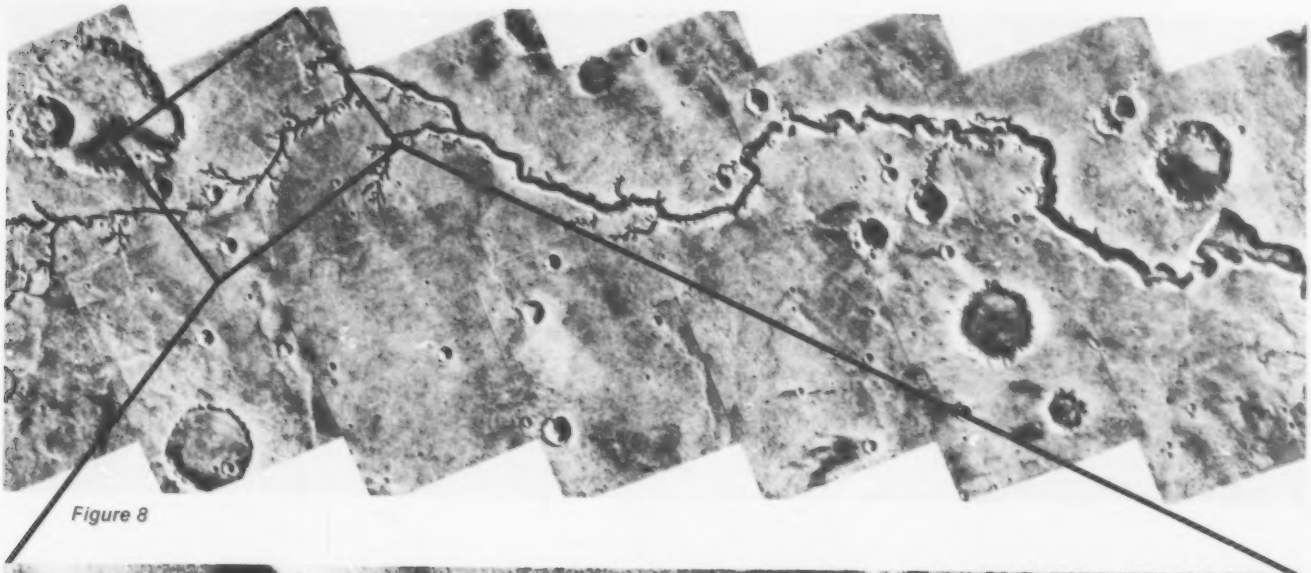


Figure 8

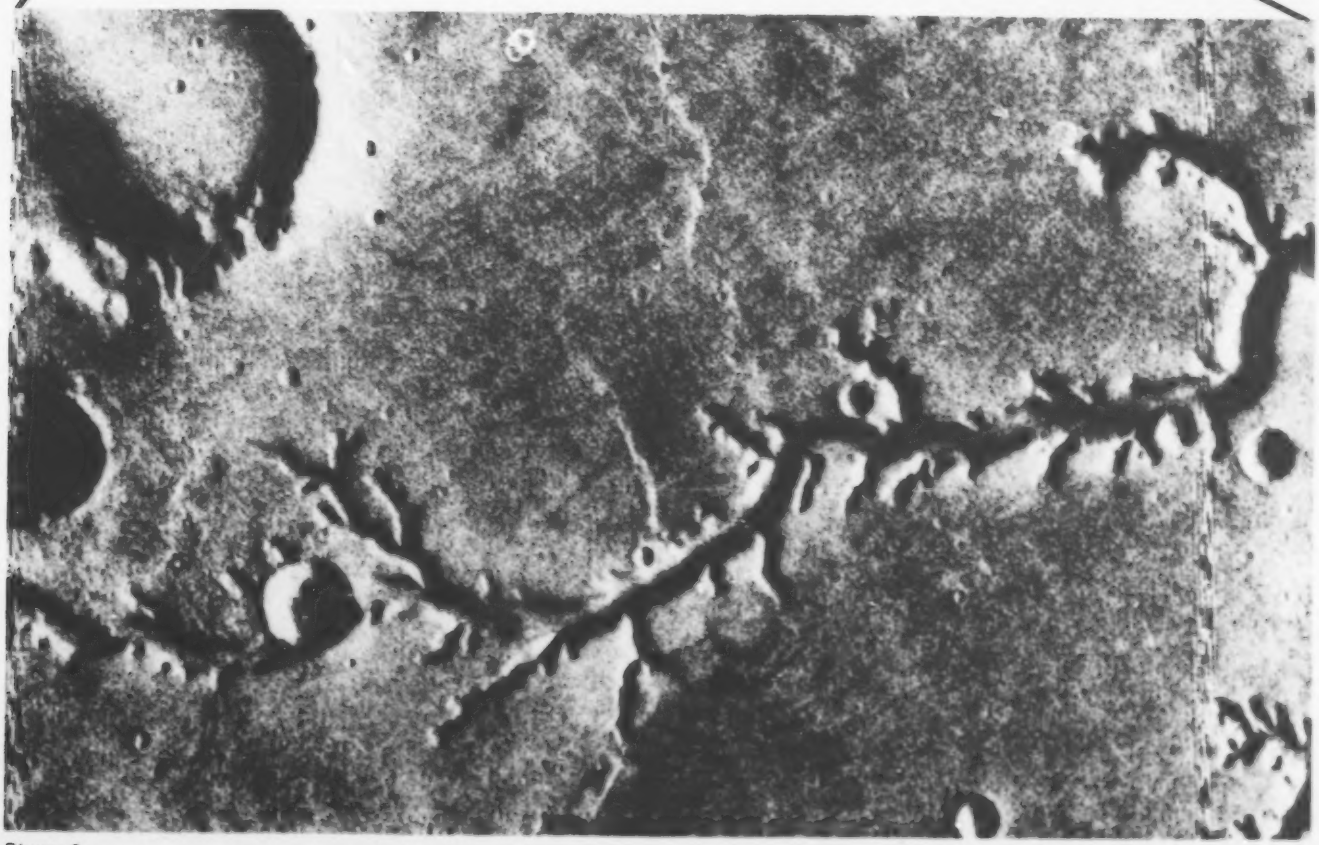


Figure 9

Close to the equator between longitudes 40° W and 100° W is a vast system of interconnected canyons, called the Valles Marineris. The west end is close to the summit of a broad rise in the Martian crust termed the Tharsis bulge, which rises 7 km (4.5 miles) above the surrounding terrain. It is on the northwest flank of this bulge that most of the large volcanoes are situated. The canyons extend down the east side of the bulge for about 4500 km (2800 miles). Individual canyons are as much as 200 km (120 miles) across and in the central section, where there are three parallel canyons, the system is 600 km (370 miles) across and over 7 km (4.5 miles) deep. Just visible in the left half of the picture on the south wall of the main canyon are tributary canyons. These are the same size as the Grand Canyon in Arizona. To the east the canyons merge with chaotic terrain which in turn merges with several large flood channels. The precise way in which the canyons form is not known, but it is thought to be a combination of faulting and erosion.

Figure 10

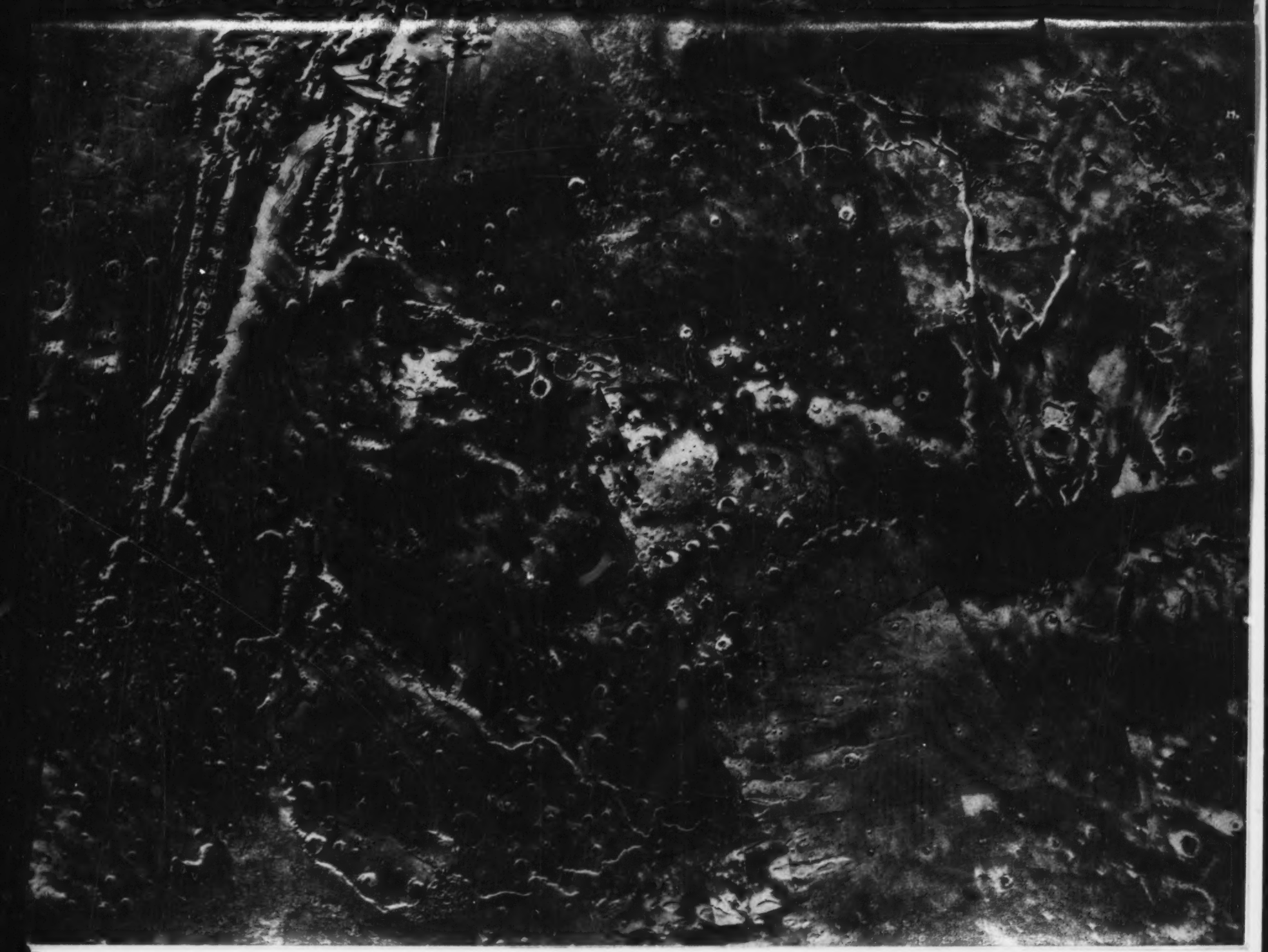


Figure 11

Looking across the canyon, the far wall rises more than 3 km (2 miles). A faint horizontal layering in the rocks exposed at the top of the wall was probably caused by lava flows. Below the rocky upper ledges are long talus slopes that reach down to the flat canyon floor. The fan-shaped feature on the floor is the edge of a large slide.

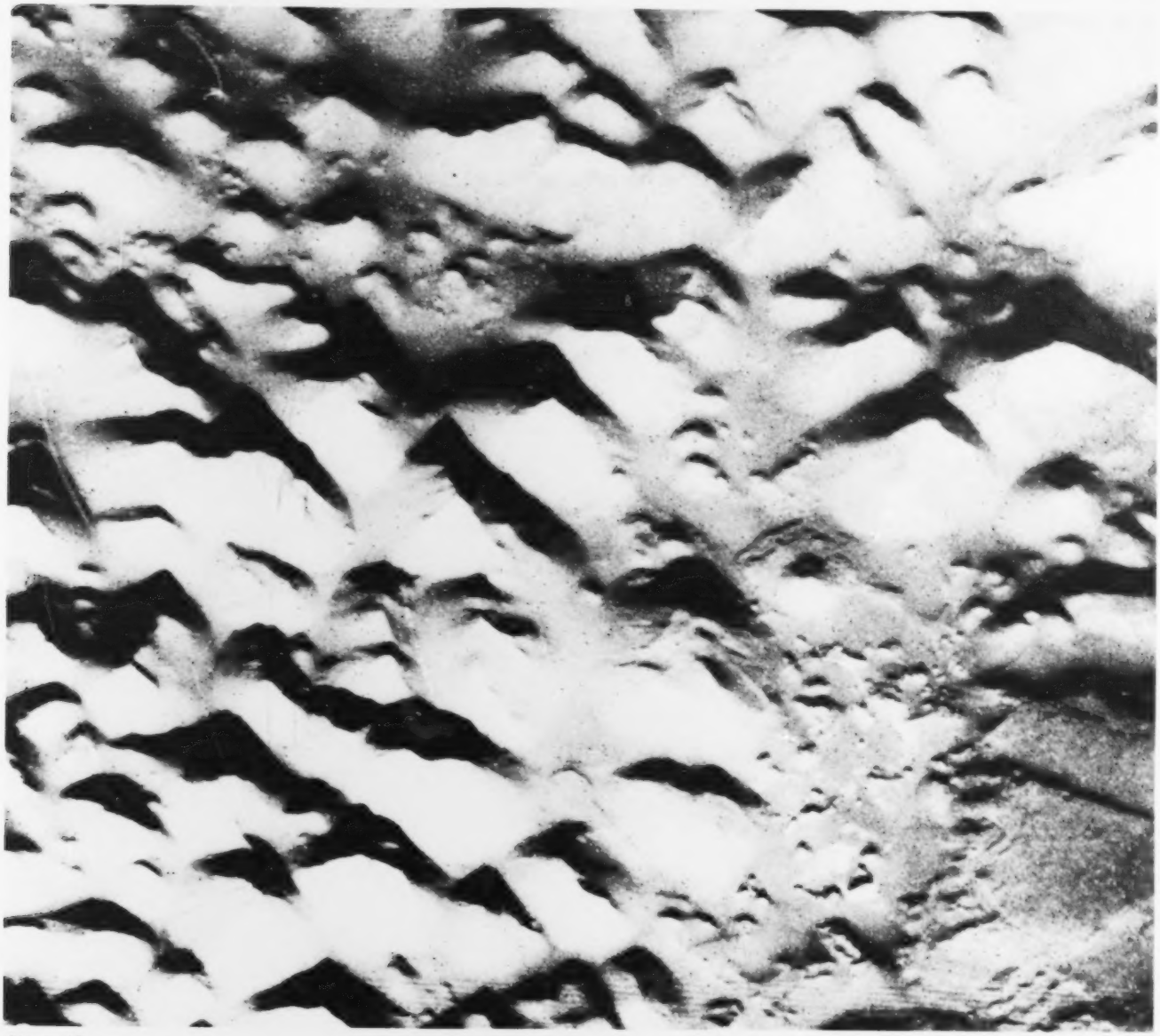


Figure 12

Many large flood features start in what has been called chaotic terrain. In these areas the ground appears to have collapsed to form a chaotic array of jostled blocks at a lower elevation than the surrounding terrain. Channels emerge full scale from these regions as though the water had come out of the ground and then the ground collapsed. This high-resolution view shows the jostled character of the terrain. The area seen here is 30 km (19 miles) across and the view is oblique with a low illumination; this gives the blocks a pyramidal appearance. Areas of chaotic terrain can also be seen at low resolution in the right side of figure 10.

Impact craters on Mars differ from those on any other planet in that they have ejecta patterns that suggest fluid flow. The material thrown out of the craters appears to have had a mud-like consistency and continued to flow outward after hitting the ground. Several layers of ejecta are visible around this 20 km (12 mile) diameter crater. Each layer has an outer ridge or rampart. The unique character is believed to result from large amounts of water being incorporated into the ejecta. When the crater formed, it may have penetrated the upper permafrost layer and excavated the water-rich materials underneath.

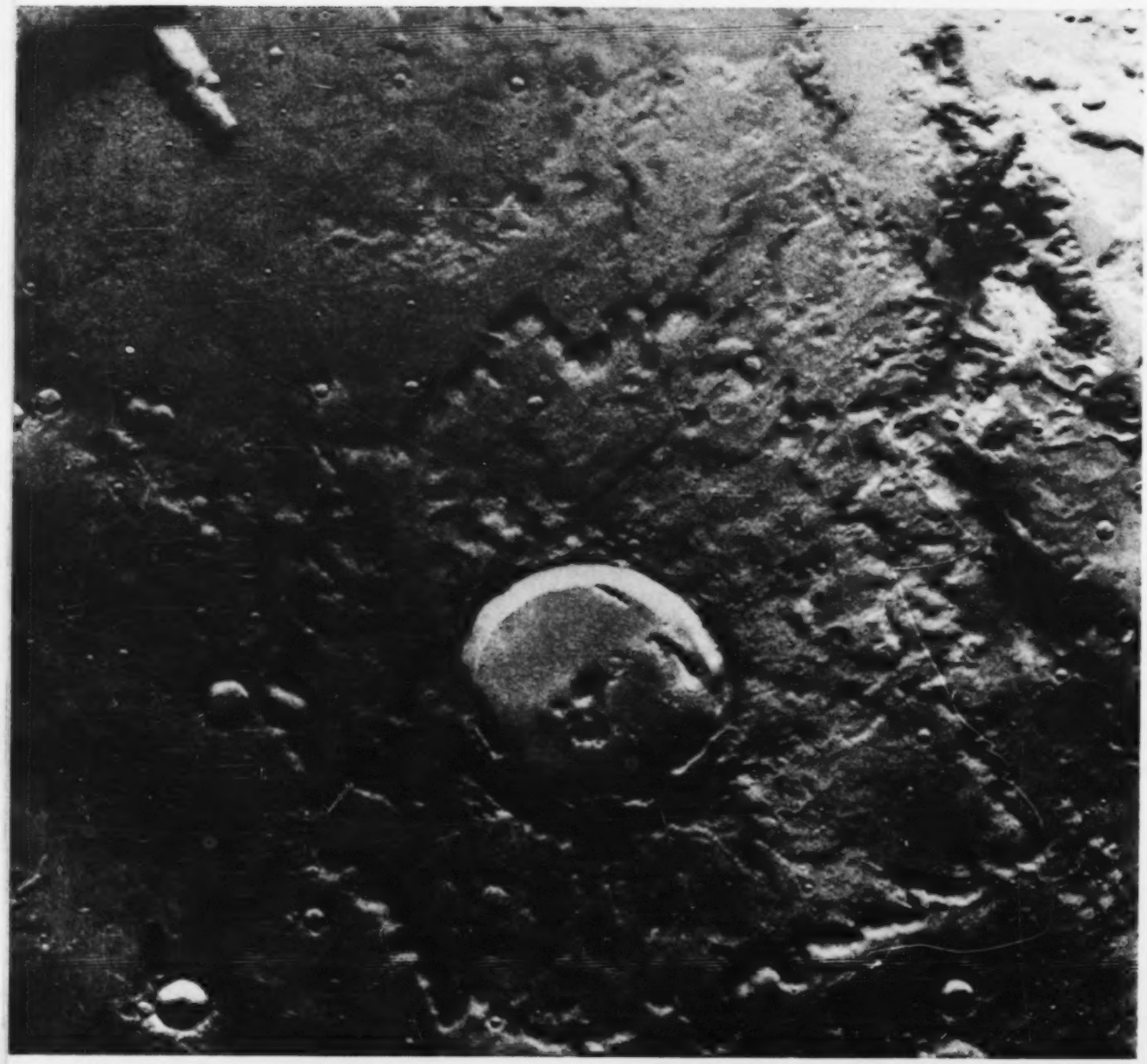


Figure 13

Terrain pockmarked with craters is seen in the high northern latitudes. The uncratered areas are dark whereas the areas around craters are light, giving the area a mottled appearance. Presumably the bright material has been excavated from below the dark, near-surface layer. Here you see a slightly different ejecta morphology. The craters are surrounded by an inner ring of ejecta that does not appear to have flowed as freely as the outer ejecta. Possibly at these high latitudes the colder temperatures inhibit the flow process, perhaps by creating a thicker permafrost. The area shown is 300 km (190 miles) across.

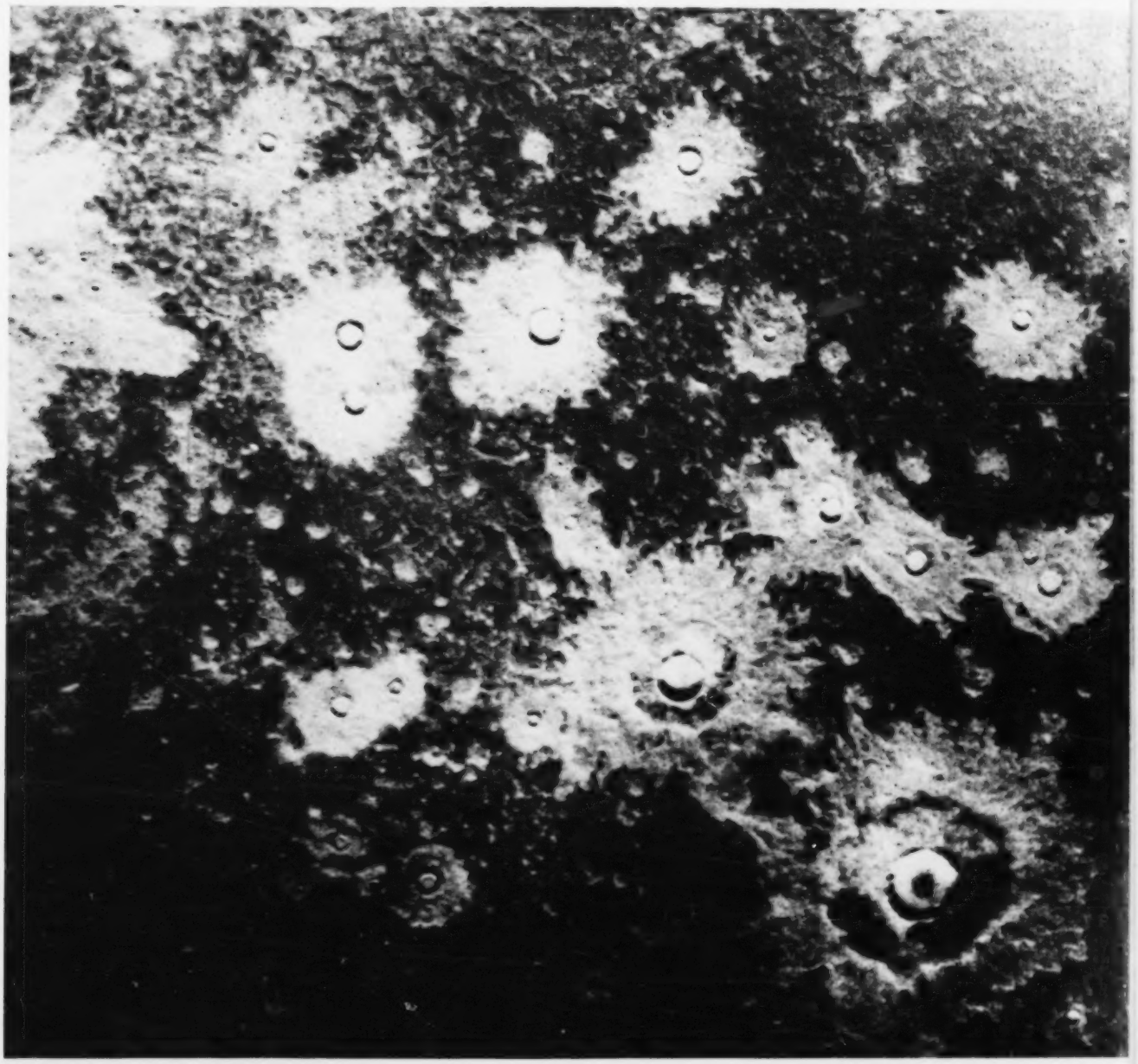


Figure 14

Figure 15

The wind has extensively modified the surface of Mars through both erosion and deposition. At large scale, the effects of wind are not obvious—other processes such as volcanism, faulting, and water erosion appear to dominate. At finer scales, however, eolian landforms become more common; in the pictures having the highest resolution, those taken with resolutions close to 10 meters, eolian features predominate. Here you see a large dune field. In the upper half are several isolated crescentic dunes indicating wind coming from the lower left. The crescentic dunes merge to the left with a large array of transverse dunes alined at right angles to the wind. The area shown is 60 km (27 miles) across.

The dunes seen in this high-resolution view have been elongated in the direction of the wind. One poorly understood aspect of dune formation on Mars is the origin of the sand-sized particles. Most of the material found at the Viking landing sites and that blown around the planet in the global dust storms is extremely fine grained and could not form dunes. The mechanics of dune formation require the particles to bounce along the ground, which dust cannot do. It has been suggested that the particles stick together electrostatically or are bound together in ice to form the required sand-sized grains. The area shown is 20 km (12 miles) across.

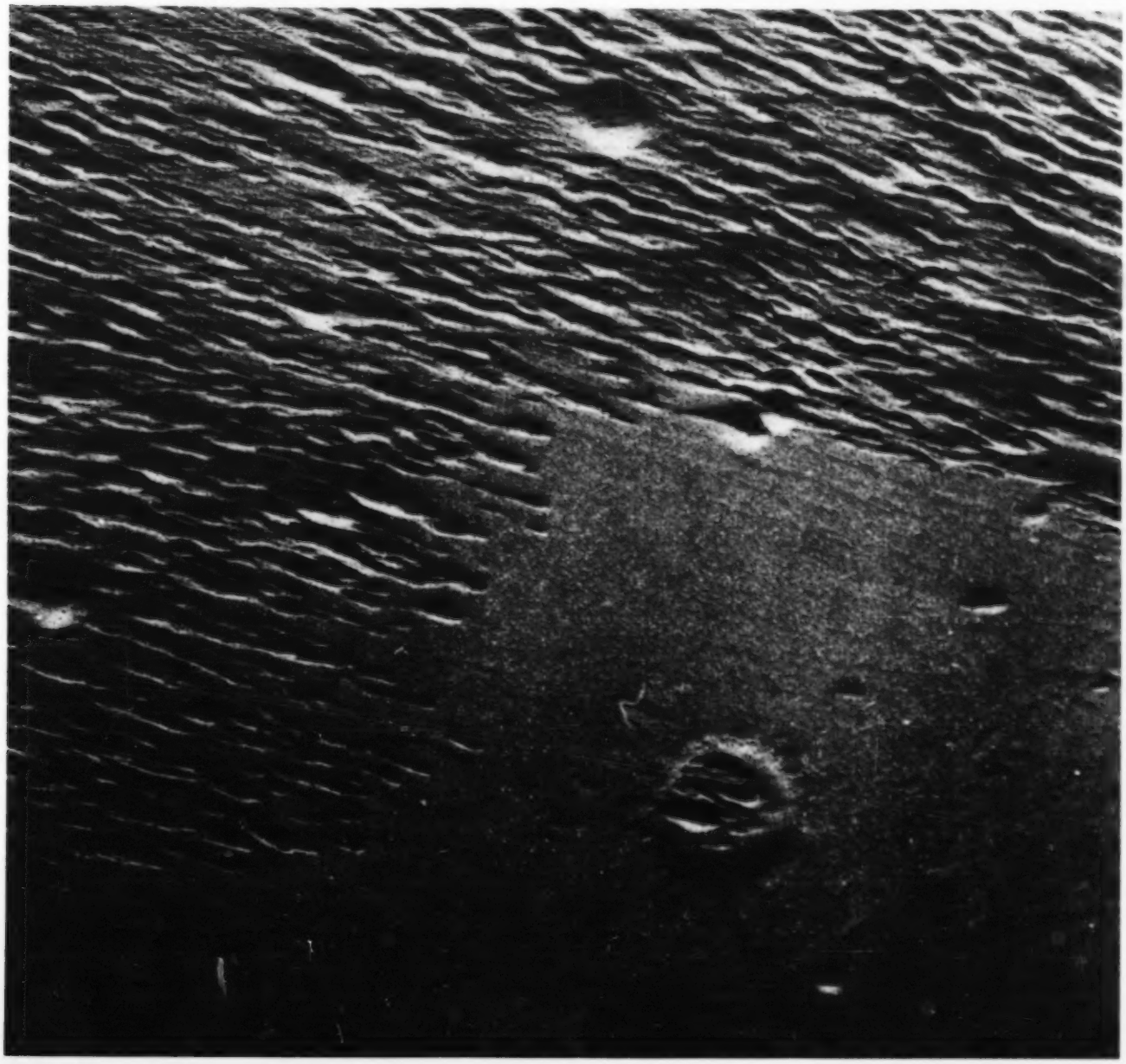


Figure 16

Wind features are especially common around the edge of Olympus Mons, possibly as a result of large topographic perturbations of the general, planet-wide circulation system. This fluted pattern southwest of Olympus Mons occurs in an area where the ground appears to have been locally etched to form hollows, probably by the wind. The area shown is approximately 20 km (12 miles) across.

Figure 17

Figure 18

An old plateau area has been deeply dissected by some unknown process. Wind-blown debris has apparently accumulated in the valleys and formed strings of dunes transverse to the length of the valleys. The upper surface of the plateau has a rough sandpaper texture that may also be the result of wind action. The area shown is 12 km (7.5 miles) across.

Figure 19

Late in the extended mission, Viking acquired contiguous high-resolution coverage of a broad swath of old cratered terrain. This is one frame (42 km, 26 miles, across) of many hundreds in that swath. The scabby appearance suggests etching of a horizontally layered surface, probably by the wind. The layers appear to have filled craters: when the layers were partly eroded away, raised platforms were left within some of the craters. The cause of the layering is not known. It is perhaps a result of wind action but depositional in nature. Recurrent episodes of deposition and erosion by the wind in this area may record climate changes of the past.

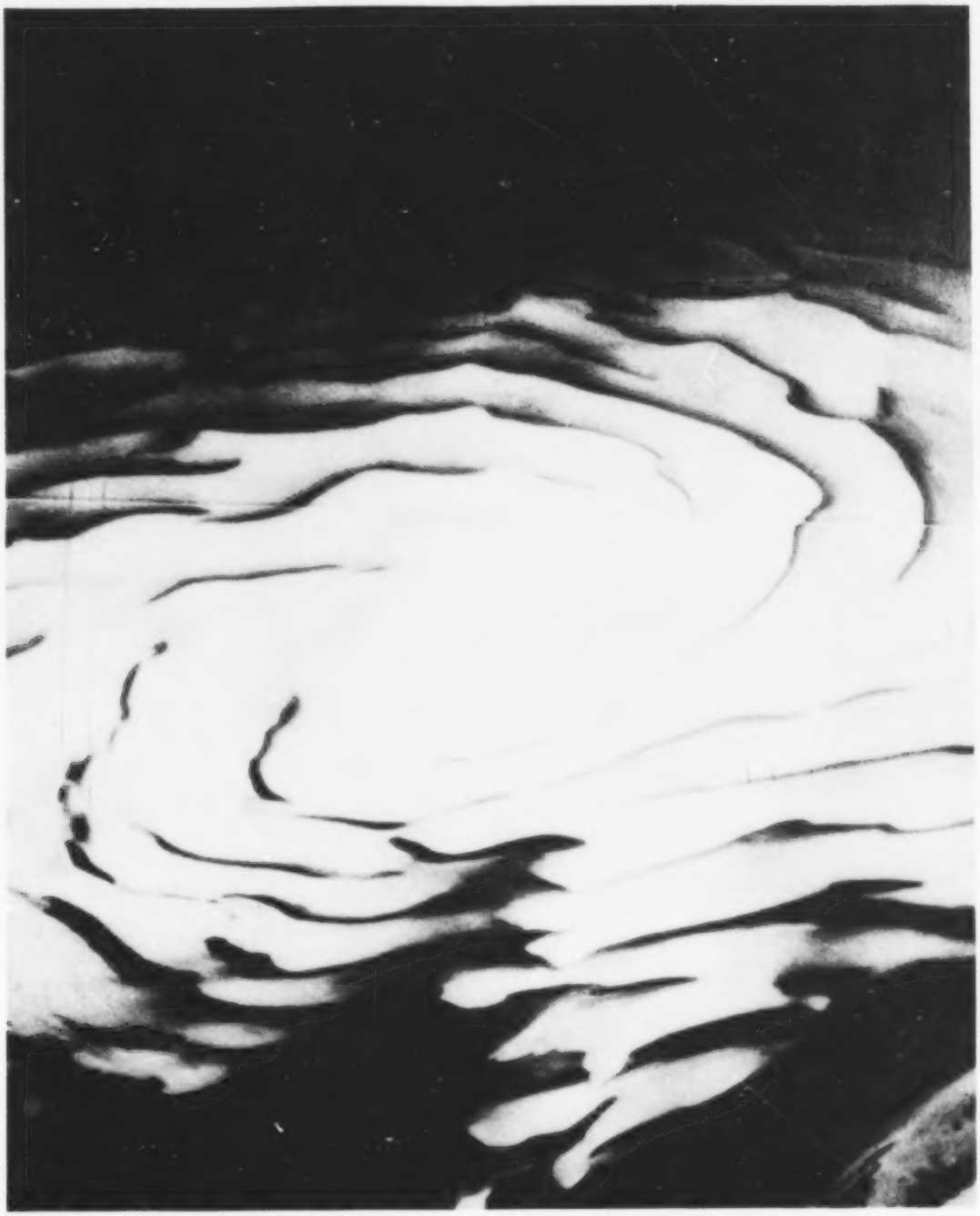


Figure 20

Both poles have caps that advance and recede with the seasons. The seasonal cap consists largely of carbon dioxide but the residual cap that remains during the summer may be water-ice, at least in the north. Large amounts of water were detected over the north pole during northern summer but not over the south pole during its summer. This is an oblique view of the residual northern cap. At the time it was a little more than 1000 km (620 miles) across. The dark lines are mostly valleys or southward-facing escarpments that are free of frost. The cause of the pattern is not known, but it may be the result of erosion by winds spiraling out from the poles.

The residual northern cap is shown in detail here. The scene, which is 90 km (56 miles) across, is difficult to visualize because of the confusing effects of the frost. The bright areas are frost covered and the dark areas are mostly frost-free. A fine pattern of striations is seen in most of the darker areas. This is caused by layered deposits that underlie the frost, causing a fine terracing of the darker sloping ground. Similar deposits occur at both poles, extending outward a little over 10° in latitude from the actual pole. They are believed to be a mixture of dust and ice that has slowly accumulated over many years. Differences between successive layers are probably the result of variations in dust storm activity. Such variations would affect the amount of dust in the atmosphere and hence the amount deposited at the poles. Thus the layering is a record of climatic variations in the recent geologic past. The layered deposits are relatively young, as indicated by the lack of superimposed impact craters.

Figure 21

The layered deposits at the north pole are never seen without the discontinuous frost cover of the remnant cap. However, in the south the remnant cap is smaller so that much of the layered deposit is unfrosted in summer. In this picture, the smooth layered deposits clearly overlie an older cratered terrain partially filling a crater (lower right). The smooth material appears to have flowed into the crater, as might be expected of ice-rich surfaces. This is somewhat conjectural. The lack of craters in the smooth area is striking. The area shown is 200 km (124 miles) across.

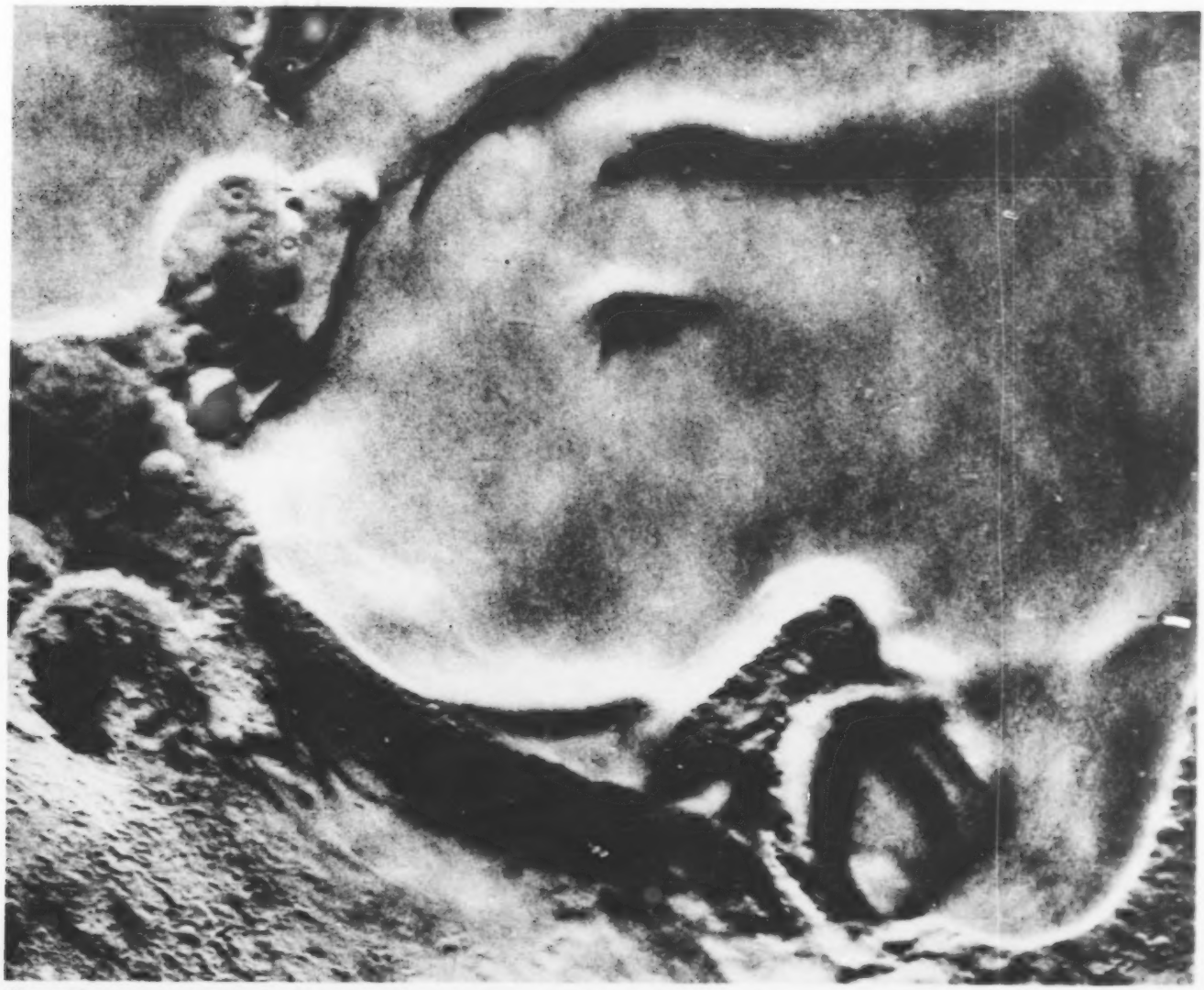


Figure 22

Figure 23

Figure 24

Since all the surface area surrounding both landers was photographed by the end of 1976, later studies concentrated on searching for changes in the scene. The picture to the upper left, taken in August 1976, has been included to show the scene as it looked then. Change A, the latest change to be identified, occurred between September 16 and September 20, 1978. It is believed to be a small-scale slide of an unstable dust layer and appears as a small circle-like formation downwind of Whale Rock. Change B, pictured in the lower left, which occurred early in 1977, shows a similar formation near Big Joe, much closer to the lander cameras. It is now believed that the dust layer that covers the surface is regularly redistributed during periods of high wind.

Figure 25

During the northern autumn, the polar cap grows to considerable size, but the process cannot be observed because it occurs beneath the dense carbon dioxide cloud cover called the polar hood. The cap condenses out of this hood and as more carbon dioxide is removed the planet-wide atmospheric pressure falls. Measurements of this pressure drop made by both landers were used to determine the volumes of carbon dioxide removed from the atmosphere. This figure divided by the areal extent of the cap (estimated to extend down to 60° N) revealed the polar cap to be several tens of centimeters thick. During the past two northern winters, however, a thin coating of water-ice has been observed at the Lander 2 site at 43° N. This covering, seen as light patches on and to the shaded side of rocks, is estimated to be 0.002 centimeter thick and is invisible from the orbiter. Water and carbon dioxide are thought to condense on dust particles, building up sufficient mass to settle to the ground. The carbon dioxide, warmed by the Sun, volatilizes rapidly, leaving the dust and water-ice that have remained on the surface for about 100 days each year.

Clouds form in the Martian atmosphere much as they do on Earth, and the types of clouds seen are similar. However, all the clouds on Earth are made up of water or water-ice. As discussed previously, the clouds that form above the polar caps are made of carbon dioxide. The clouds seen on volcano slopes (as early morning fog in deep valleys) and in storm fronts (like these cyclonic storms) are made up of water or water-ice, as indicated by measurements taken by the Infrared Thermal Mapper (IRTM) and the Mars Atmospheric Water Detector (MAWD) instruments on the orbiter. These cyclones and other frontal storms were detected on the surface by pressure indicators on Lander 2 and were noted to pass by every 3 to 4 days during the late fall and winter. Cyclones occur when the

Figure 26

cold polar air flows under warmer air at a lower latitude.

The storm shown at left is approximately 250 km (155 miles) across while the storm shown below is about 600 km (375 miles) across. An estimate made from the cloud shadows of the storm below indicates that it is 6 to 7 km (4 miles) above the surface.

Figure 27

One striking effect on Mars is the formation of global dust storms. They are thought to occur nearly every Martian year and begin in the southern hemisphere during the summer. During the southern spring many small local storms, such as this one, are seen in areas where high winds eventually develop. A local storm is seen here in Argyre, a large, 1000 km (620 mile) diameter impact basin near the south polar region. Half of the floor is still covered with frost while the high polar winds lift dust into the atmosphere from the other half.

Figure 28

As more and more dust enters the atmosphere, the dusty atmosphere heats up more rapidly during the day, resulting in increased temperature differences between night and day in the upper atmosphere. Such differences cause large winds that pick up more dust so that the storms feed on themselves and spread rapidly over the planet. Prior to Viking each dust storm season was thought to be much the same; however, last Mars year the storm was so mild it did not reach global scale. The previous year, just after Viking's arrival, was marked by two full-scale global storms.

Here the southern hemisphere is completely engulfed in a north-spreading storm. Toward the top of the picture, the canyons are just visible at the edge of the storm. It is thought that a global-scale storm cuts itself off when so much dust is in the atmosphere that the sunlight is filtered out and peak temperatures at the surface fall. The winds then drop and the dust settles out. It takes about 3 months for the atmosphere to become clear again.

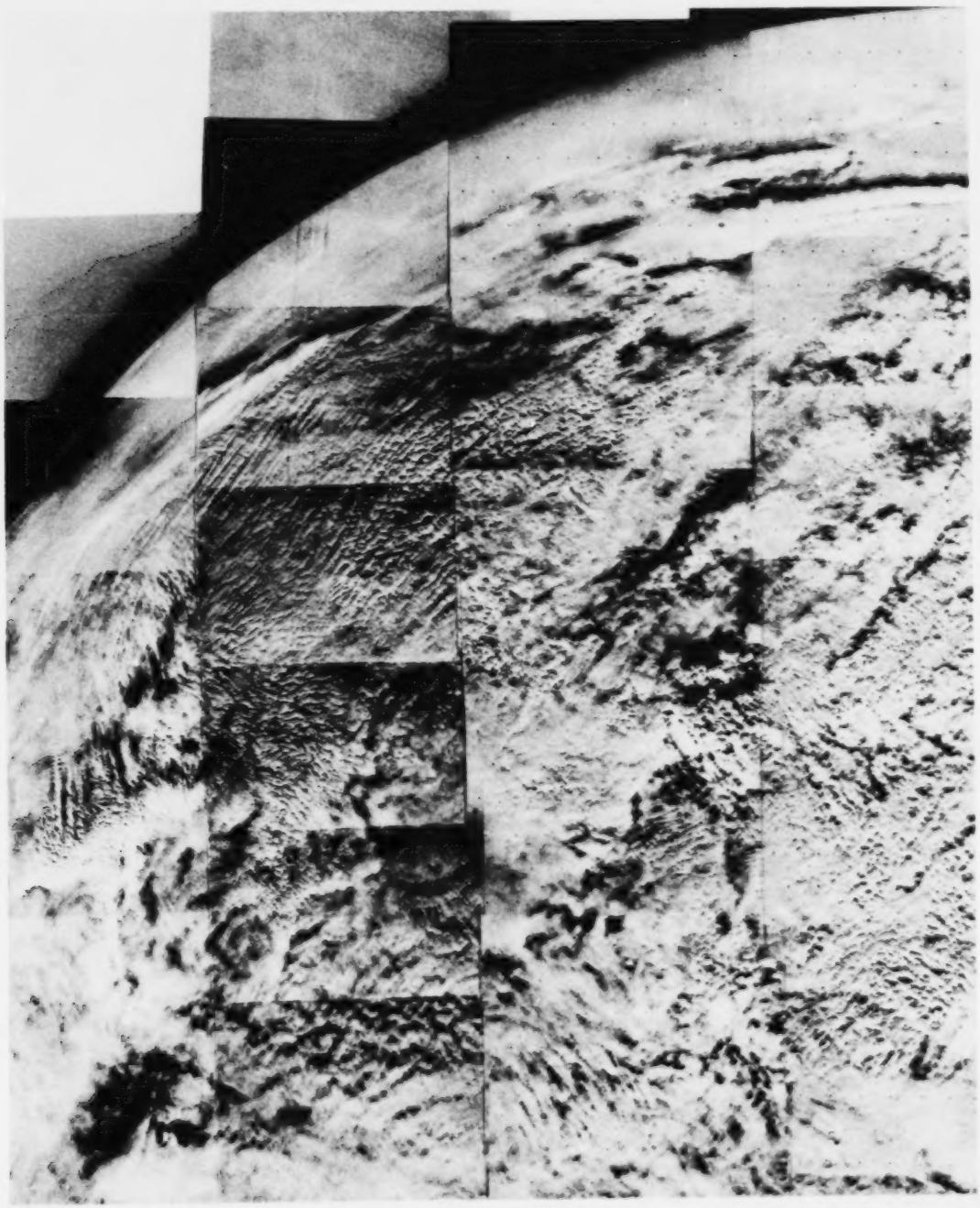


Figure 29

Figure 30

Two irregularly shaped moons, Phobos and Deimos, orbit Mars. The picture to the left is of Phobos, which is 24 km (15 miles) across and circles Mars every 7.6 hours at an altitude of 6000 km (3700 miles). Deimos, in the picture below, is 12 km (7.5 miles) across and circles the planet every 1.3 days at an altitude of 24 000 km (15 000 miles). Somewhat surprisingly, the two satellites look very different. Phobos has crisp craters and is crossed by numerous fractures which are barely visible in this picture. Demios appears much smoother and the craters have a softer appearance. The cause of the difference is not known.

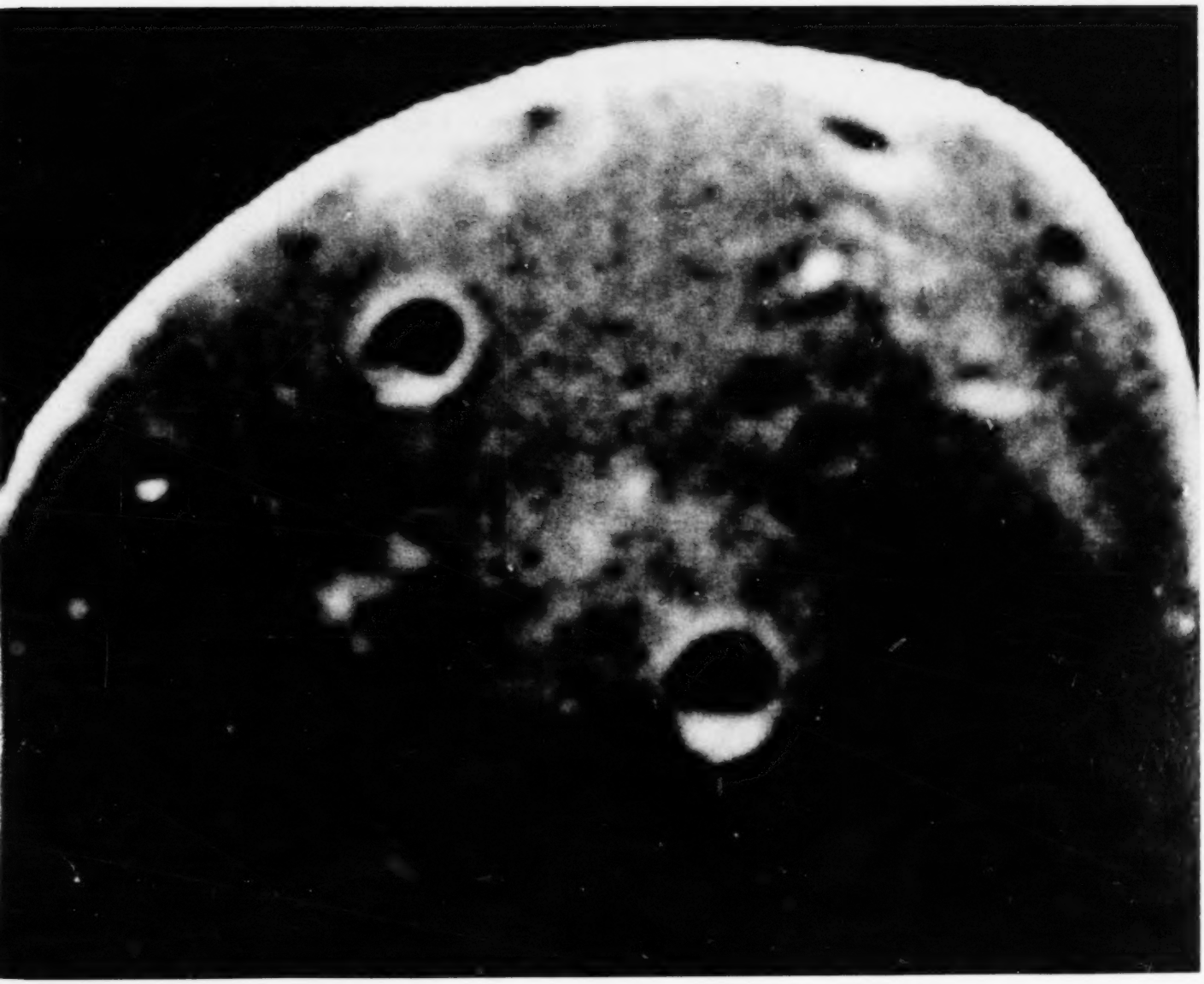


Figure 31

The Viking Spacecraft

On July 20, 1976, the first Viking spacecraft landed on the Martian surface, followed by a second on September 3, 1976. Almost 4 years later, the two landers are still operating, as is one of the orbiters. A second orbiter was powered down on July 25, 1978, after it ran out of attitude control gas. For almost 2 Martian years the landers have been observing changes at the landing sites and making meteorological measurements. Meanwhile the orbiters have been systematically photographing the surface and watching seasonal changes in the atmosphere.

The entire surface has been photographed at a resolution of 200 meters (625 ft) and a significant fraction at resolutions ranging down to 8 meters (26 ft). Changing meteorological conditions were observed over the entire planet during this period, including the waxing and waning of global dust storms. Changes at the polar caps were also observed as the seasonal carbon dioxide formed and dissipated, leaving behind a remnant summer cap that is mostly water-ice in the north and carbon dioxide ice in the south. Finally the orbiters made close encounters with the two Martian moons, at one point passing within 30 km of Deimos and obtaining the highest-resolution pictures ever taken of another object from an orbiter or flyby spacecraft.

VIKING ORBITER 1 CHRONOLOGY

Date	Revolution	Event
June 19, 1976	0	Mars orbit insertion
June 21, 1976	2	Trim to planned site-certification orbit
July 9, 1976	19	Orbit trim to move westward
July 14, 1976	24	Synchronous orbit over landing site
July 20, 1976	30	VL-1 landing at 1153:06 UTC
Aug. 3, 1976	43	Minor orbit trim to maintain synchronization over VL-1
Sept. 3, 1976	75	VL-2 landing
Sept. 11, 1976	82	Decrease of orbit period to begin eastward walk
Sept. 20, 1976	92	Orbit trim to permit synchronization over VL-2
Sept. 24, 1976	96	Synchronous orbit over VL-2
Nov. 25, 1976	156	Solar conjunction
Jan. 22, 1977	213	Period change to approach Phobos
Feb. 4, 1977	227	Orbit synchronization with Phobos period
Feb. 12, 1977	235	Precise correction to Phobos synchronization
March 11, 1977	263	Reduction of periapsis to 300 km
March 24, 1977	278	Adjustment of orbit period to 23.5 hours
May 15, 1977	331	Small Phobos-avoidance maneuver
July 1, 1977	379	Adjustment of orbit period to 24.0 hours
Dec. 2, 1978	898	Adjustment of orbit period to 24.85 hours; beginning slow walk around planet
May 19, 1978	1061	Adjustment of orbit period to 25.0 hours; acceleration of walk rate
July 20, 1979	1120	Raising of periapsis to 357 km; adjustment of orbit period to 24.8 hours; and slowing of walk rate.

VIKING ORBITER 2 CHRONOLOGY

Date	Revolution	Event
Aug. 7, 1976	0	Mars orbit insertion
Aug. 9, 1976	2	Period and altitude adjustment; begin westward walk
Aug. 14, 1976	6	Increase of period to increase walk rate
Aug. 25, 1976	16	Decrease of walk rate to proceed to landing site
Aug. 27, 1976	18	Synchronous orbit over landing site
Sept. 3, 1976	25	VL-2 landing at 2237:50 UTC
Sept. 30, 1976	51	Change of orbit plane to 75° inclination and beginning of westward walk
Nov. 25, 1976	101	Solar conjunction
Dec. 20, 1976	123	Lowering of periapsis to 800 km and increasing of inclination to 80°
March 2, 1977	189	Synchronous over VL-2
April 18, 1977	235	Period change: 13 revolutions equals 12 Mars days
Sept. 25, 1977	404	Change of orbit period to approach Deimos
Oct. 9, 1977	418	Orbit synchronization with Deimos
Oct. 23, 1977	432	Change of orbit period to 24.0 hours and lowering of periapsis to 300 km
July 25, 1978	706	Power down

Figure	Picno	Neg number
Figure 1	646A28	M3036-036
Figure 2	731A41	M3208-017
Figure 3	146S23	M3497-018
Figure 4	627A28	M1993-008
Figure 5	Mosaic	211-5642
Figure 6	664A56	M3072-006
Figure 7	541A20	P1867-004
Figure 8	Mosaic	211-5540
Figure 9	466A54	P1768-010
Figure 10	Mosaic	211-TBD
Figure 11	737A65	M3221-023
Figure 12	743A15	M3232-010
Figure 13	673A12	M3014-012
Figure 14	673B30	M2851-006
Figure 15	575B60	M2806-022
Figure 16	728A64	M3204-014
Figure 17	693A38	P3125-014
Figure 18	763A16	M3280-007
Figure 19	184S11	M3545-014
Figure 20	Mosaic	211-5812
Figure 21	56B86	M2111-018
Figure 22	383B49	M2518-025
Figure 23	Panorama	P21077
Figure 24	Panorama	P21077
Figure 25	Panorama	P21841
Figure 26	738A27	M3223-027
Figure 27	783A42	M3303-043
Figure 28	211B24	77-10-15-002005
Figure 29	Mosaic	P19321
Figure 30	Mosaic	P20776
Figure 31	413B83	77-10-28-164455

Cover: This painting by Gordon Legg of Graphic Films, Inc., Hollywood, Calif., was done for a NASA film of Viking. The multi-ringed caldera atop Olympus Mons rises above the cloud bank which obscures the lower two-thirds of the volcano. The painting is based on Viking images obtained July 31, 1976, from Viking Orbiter 1.

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